Tetra Tech EM Inc.

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December 21, 2004

Mr. Roy Crossland
START Project Officer
U.S. Environmental Protection Agency, Region 7
901 North 5th Street
Kansas City, Kansas 66101

Subject: **Lead Trend Analysis - Evaluation by Individual Quadrants**
Herculaneum Lead Smelter
U.S. EPA Region 7 START 2, Contract No. 68-S7-01-41, Task Order No. 0027
Task Monitor: Bruce Morrison, On-Scene Coordinator

Dear Mr. Crossland:

Tetra Tech EM Inc. is submitting the attached revised Lead Trend Analysis at the Herculaneum Lead Smelter. Tetra Tech has revised the trend analysis to evaluate each quadrant separately and then compared these results to previous evaluation of the data pool for each house. If you have any questions or comments, please contact the program manager at (913) 495-3911.

Sincerely,

David Homer
Project Manager

for Hieu Q. Vu, PE, CHMM
START Program Manager

cc: Bruce Morrison, EPA

Enclosures

G9011/0027

LEAD SOIL TREND ANALYSIS
THROUGH SEPTEMBER, 2004
EVALUATION BY INDIVIDUAL QUADRANT
Herculaneum Lead Smelter Site
Herculaneum, Missouri

Tetra Tech EM Inc. (Tetra Tech) was tasked by the U.S. Environmental Protection Agency (EPA) Region 7 Enforcement/Fund Lead Removal program to conduct a trend analysis of soil lead concentrations at selected locations within Herculaneum, Missouri (City). Specifically, the Tetra Tech Superfund Technical Assessment and Response Team (START) 2 was requested to review and analyze data that would enable EPA to determine if soil lead concentrations are increasing over time at a variety of locations within the City. Tetra Tech had previously performed this analysis and was requested to repeat the analysis using the most current sampling data by evaluating the trends for each sampling quadrant. The assessment was conducted under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the Superfund Amendments and Reauthorization Act of 1986. The project was assigned under START Contract No. 68-S7-01-41, Task Order No. 0027.

Tetra Tech focused its analysis on one data set called "Recontamination" that includes results from a number of residential properties. The data were collected from four different quadrants at each property, and additional data for several properties came from samples collected in driveway areas outside the quadrants. Lead concentrations were estimated at each location at approximately monthly intervals from the time removal activities were completed until September 2004 (sampling round 18). Due to the sequence of removal activities, not all properties underwent the same number of sampling events; the number of events ranged from 4 to 12 events per residence. At many locations, some intervals within the series were omitted because of weather or access restrictions. The lead concentrations were determined by use of a portable X-ray fluorescence (XRF) instrument. Samples were collected and analyzed in accordance with the quality assurance project plan (QAPP) dated September 11, 2001.

This document presents the methods used to evaluate changes in soil lead concentrations following the removal activities, and the results of this analysis.

Methods

Temporal trends in lead concentrations for 24 properties are summarized in Table 1. Trend tests were conducted for each property using all data collected from round 7 (August 2002) through round 18 (September 2004). The non-parametric Mann-Kendall test was used to evaluate temporal trends for each sampled quadrant at the individual properties. The Mann-Kendall test is a widely used statistical test for detecting monotonic trends (that is, trends either increasing or decreasing) in time-series of data (Gilbert 1987; Helsel and Hirsch 1992; Gibbons 1994). Because the Mann-Kendall test uses only the relative magnitude of the data rather than their measured values, it has a number of desirable properties: the data need not be normally distributed; and the test is not significantly affected by outliers, missing data, or censored data. Censored data are treated in the Mann-Kendall test by setting all non-detect values to a concentration slightly below the minimum detected concentration. It should be noted that a minimum of four sampling events are required to perform this test, so properties with fewer than four rounds of sampling were not evaluated.

Results

The analysis of the temporal trends in lead concentrations identified 18 of the 24 properties containing at least one quadrant with a statistically significant trend: House Numbers 20, 101, 102, 5, 6, 22, 24, 12, 13, 17, 21, 11, 9, 16, 21, 11, 9, 16, 19, 18, 3, and 7. Only two properties had temporal trends with increasing lead concentrations in all four quadrants: House Numbers 20 and 5. Four properties had temporal trends with increasing lead concentrations in three of four quadrants: House Numbers 22, 12, 17, and 9. Five properties had temporal trends with increasing lead concentrations in two of four quadrants: House Numbers 24, 16, 19, 3, and 7. The remaining houses identified above had only one quadrant with a statistically significant trend in temporal trends in lead concentration. Six properties showed no statistically significant trend in lead concentrations.

A statistical analysis had been performed pooling all the data from each quadrant for a specific property (Tetra Tech 2004). For this analysis, trends were evaluated using the median lead concentration of the combined data for all four quadrants. This analysis identified 14 properties with statistically significant increases in the temporal trend of the lead concentration; these results are summarized in Table 2. Most properties that had at least two quadrants with a statistically significant increasing trend in lead

concentration also had a statistically significant increasing trend in lead concentration when the data for the property were pooled. Exceptions were noted for five properties: House Numbers 101, 6, and 18 had only one quadrant with an increase, but the pooled data showed an increasing trend; House Number 19 had two quadrants with increases, but the pooled data showed no increase; and House Number 8 had no quadrants with an increasing trend, but the pooled data showed an increase. It should also be noted that House Number 8 had a high number of censored data, and therefore statistical analysis of the data from this property is uncertain.

A spatial analysis of properties with at least two quadrants with a statistically significant increasing temporal trend in lead concentration did not identify any clear relationship between the house location and the haul routes. All properties within 0.45 mile of the smelter except for House Number 76 had at least one quadrant with a statistically significant trend.

Trend testing based on a median response versus trend testing based on the response for individual quadrants involve two different approaches, so direct comparison of the results isn't straightforward. For future analyses, Tetra Tech recommends conducting both analyses. Quadrant-specific analyses are the only way to identify spatial trends within a yard. If there is significant spatial heterogeneity at the scale of an individual yard, quadrant-specific trends could be lost or obscured if only pooled data are analyzed. However, if concentrations are homogeneous (and changing at the same rate over time), pooling provides greater precision in estimating the true mean response within each yard. Re-contamination could be occurring through aerial deposition, which would show up as a more uniform increase of lead for an individual yard, and through deposition associated with haul routes and other road ways, which might be reflected in an increase in only one or a subset of quadrants within an individual yard. Therefore, evaluating both quadrant-specific and pooled data for each home will ensure detections of any increasing (or decreasing) trends in lead concentrations.

References:

Gibbons, R. D. 1994. *Statistical Methods for Groundwater Monitoring.* John Wiley & Sons, Inc. New York, New York.

Gilbert, R. O. 1987. *Statistical Methods in Environmental Pollution Monitoring.* John Wiley & Sons, Inc. New York, New York.

Helsel, D. R. and R. M. Hirsh. 1992. *Statistical Methods in Water Resources.* Elsevier. New York, New York.

Tetra Tech EM Inc. (Tetra Tech). 2004. *Lead Soil Trend Analysis Through September, 2004, Herculaneum Lead Smelter Site, Herculaneum, Missouri*, For U.S. EPA Region 7 START. October.

TABLE 1

RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST) IN LEAD CONCENTRATION
INDIVIDUAL QUADRANTS FOR SAMPLING ROUNDS 7 THROUGH 18
HERCULANEUM LEAD SMELTER SITE - HERCULANEUM, MISSOURI

Distance From Smelter[1] (miles)	House Number	Address	Quadrant	Number of Sampling Events[2]	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic[3] (S)	Probability > S	Trend Significant?[4] (Yes/No)	Direction of Trend	Notes
						First	Last					
0.10	76	329 Station	Q1	5	5	10/30/2003	09/23/2004	4	0.242	No	N/A	
			Q2	5	5	10/30/2003	09/23/2004	4	0.242	No	N/A	
0.20	20	928 Church	Q1	11	11	08/26/2002	09/23/2004	39	0.003	**Yes**	**Increasing**	
			Q2	11	11	08/26/2002	09/23/2004	25	0.035	**Yes**	**Increasing**	
			Q3	11	11	08/26/2002	09/23/2004	43	0.001	**Yes**	**Increasing**	
			Q4	11	11	08/26/2002	09/23/2004	33	0.009	**Yes**	**Increasing**	
	101	339 Curved	Q1	4	4	12/22/2003	09/23/2004	0	0.625	No	N/A	
			Q2	4	3	12/22/2003	09/23/2004	2	0.375	No	N/A	
			Q3	4	4	12/22/2003	09/23/2004	4	0.167	No	N/A	
			Q4	4	4	12/22/2003	09/23/2004	6	0.042	**Yes**	**Increasing**	
	102	959 Main	Q1	4	4	12/22/2003	09/23/2004	6	0.042	**Yes**	**Increasing**	
			Q2	4	4	12/22/2003	09/23/2004	0	0.625	No	N/A	
			Q3	4	4	12/22/2003	09/23/2004	4	0.167	No	N/A	
			Q4	4	4	12/22/2003	09/23/2004	4	0.167	No	N/A	
0.25	5	407 Burris	Q1	11	8	08/26/2002	09/23/2004	39	0.002	**Yes**	**Increasing**	
			Q2	11	10	08/26/2002	09/23/2004	33	0.009	**Yes**	**Increasing**	
			Q3	11	11	08/26/2002	09/23/2004	40	0.002	**Yes**	**Increasing**	
			Q4	11	11	08/26/2002	09/23/2004	29	0.019	**Yes**	**Increasing**	
	6	907 Dale	Q1	11	11	08/23/2002	09/23/2004	5	0.190	No	N/A	
			Q2	11	11	08/23/2002	09/23/2004	43	0.001	**Yes**	**Increasing**	
			Q3	11	11	08/23/2002	09/23/2004	15	0.110	No	N/A	
			Q4	11	11	08/23/2002	09/23/2004	15	0.110	No	N/A	
	22	824 Brown	Q1	10	10	08/26/2002	09/23/2004	19	0.054	No	N/A	
			Q2	10	10	08/26/2002	09/23/2004	31	0.002	**Yes**	**Increasing**	
			Q3	10	10	08/26/2002	09/23/2004	34	0.001	**Yes**	**Increasing**	
			Q4	10	10	08/26/2002	09/23/2004	25	0.014	**Yes**	**Increasing**	
	24	812 Brown	Q1	9	9	11/07/2002	09/23/2004	14	0.090	No	N/A	
			Q2	9	9	11/07/2002	09/23/2004	18	0.038	**Yes**	**Increasing**	
			Q3	9	9	11/07/2002	09/23/2004	10	0.179	No	N/A	
			Q4	9	8	11/07/2002	09/23/2004	19	0.030	**Yes**	**Increasing**	

TABLE 1

RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST) IN LEAD CONCENTRATION

INDIVIDUAL QUADRANTS FOR SAMPLING ROUNDS 7 THROUGH 18

HERCULANEUM LEAD SMELTER SITE - HERCULANEUM, MISSOURI

Distance From Smelter[1] (miles)	House Number	Address	Quadrant	Number of Sampling Events[2]	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic[3] (S)	Probability > S	Trend Significant?[4] (Yes/No)	Direction of Trend	Notes
						First	Last					
0.40	12	292 Park	Q1	12	9	08/23/2002	09/23/2004	35	0.013	**Yes**	**Increasing**	
			Q2	12	7	08/23/2002	09/23/2004	26	0.040	**Yes**	**Increasing**	
			Q3	12	10	08/23/2002	09/23/2004	29	0.031	**Yes**	**Increasing**	
			Q4	12	11	08/23/2002	09/23/2004	16	0.118	No	N/A	
	13	562 Reservoir	Q1	7	7	08/23/2002	06/23/2003	13	0.035	**Yes**	**Increasing**	
			Q2	7	7	08/23/2002	06/23/2003	1	0.500	No	N/A	
			Q4	7	6	08/23/2002	06/23/2003	3	0.386	No	N/A	
	17	416 Thurwell	Q1	11	11	08/22/2002	09/23/2004	29	0.018	**Yes**	**Increasing**	
			Q2	11	11	08/22/2002	09/23/2004	23	0.046	**Yes**	**Increasing**	
			Q3	11	11	08/22/2002	09/23/2004	23	0.046	**Yes**	**Increasing**	
			Q4	11	9	08/22/2002	09/23/2004	18	0.083	No	N/A	
	21	295 Broadway	Q1	7	5	08/23/2002	09/23/2004	6	0.236	No	N/A	
			Q2	7	7	08/23/2002	09/23/2004	9	0.119	No	N/A	
			Q3	7	7	08/23/2002	09/23/2004	11	0.068	No	N/A	
			Q4	7	7	08/23/2002	09/23/2004	17	0.005	**Yes**	**Increasing**	
0.45	11	525 Joachim	Q1	5	5	08/26/2002	03/17/2003	-6	0.117	No	N/A	
			Q2	5	5	08/26/2002	03/17/2003	2	0.408	No	N/A	
			Q3	5	4	08/26/2002	03/17/2003	8	0.042	**Yes**	**Increasing**	
			Q4	5	4	08/26/2002	03/17/2003	-2	0.408	No	N/A	
0.50	14	440 Thurwell	Q1	5	5	09/16/2002	06/23/2003	-6	0.117	No	N/A	
			Q2	5	2	09/16/2002	06/23/2003	5	0.180	No	N/A	
			Q3	5	5	09/16/2002	06/23/2003	4	0.242	No	N/A	
			Q4	5	4	09/16/2002	06/23/2003	-6	0.117	No	N/A	
	16	695 Joachim	Q1	9	6	09/16/2002	09/23/2004	1	0.500	No	N/A	
			Q2	9	3	09/16/2002	09/23/2004	21	0.017	**Yes**	**Increasing**	*
			Q3	9	4	09/16/2002	09/23/2004	14	0.090	No	N/A	*
			Q4	9	5	09/16/2002	09/23/2004	20	0.022	**Yes**	**Increasing**	
	19	407 Hill	Q1	11	10	08/22/2002	09/23/2004	20	0.066	No	N/A	
			Q2	11	8	08/22/2002	09/23/2004	6	0.185	No	N/A	
			Q3	11	9	08/22/2002	09/23/2004	24	0.040	**Yes**	**Increasing**	
			Q4	11	10	08/22/2002	09/23/2004	30	0.015	**Yes**	**Increasing**	
0.54	9	454 Hill	Q1	11	11	08/22/2002	09/23/2004	28	0.022	**Yes**	**Increasing**	
			Q2	11	11	08/22/2002	09/23/2004	24	0.040	**Yes**	**Increasing**	
			Q3	11	11	08/22/2002	09/23/2004	21	0.059	No	N/A	
			Q4	11	10	08/22/2002	09/23/2004	24	0.040	**Yes**	**Increasing**	

TABLE 1

RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST) IN LEAD CONCENTRATION

INDIVIDUAL QUADRANTS FOR SAMPLING ROUNDS 7 THROUGH 18

HERCULANEUM LEAD SMELTER SITE - HERCULANEUM, MISSOURI

Distance From Smelter[1] (miles)	House Number	Address	Quadrant	Number of Sampling Events[2]	Number of Detected Samples	Sampling Event		Mann-Kendall Test Statistic[3] (S)	Probability > S	Trend Significant?[4] (Yes/No)	Direction of Trend	Notes
						First	Last					
0.60	4	438 Washington	Q1	6	2	08/22/2002	03/14/2003	3	0.360	No	N/A	*
			Q2	6	2	08/22/2002	03/14/2003	1	0.500	No	N/A	*
			Q3	6	3	08/22/2002	03/14/2003	6	0.186	No	N/A	*
			Q4	6	4	08/22/2002	03/14/2003	-2	0.430	No	N/A	
	18	422 Reservior	Q1	12	12	08/23/2002	09/23/2004	14	0.134	No	N/A	
			Q2	12	11	08/23/2002	09/23/2004	-6	0.188	No	N/A	
			Q3	12	12	08/23/2002	09/23/2004	29	0.031	**Yes**	**Increasing**	
			Q4	12	12	08/23/2002	09/23/2004	20	0.085	No	N/A	
0.75	3	441 Main	Q1	12	10	08/23/2002	09/23/2004	3	0.198	No	N/A	
			Q2	12	10	08/23/2002	09/23/2004	29	0.031	**Yes**	**Increasing**	
			Q3	12	11	08/23/2002	09/23/2004	-2	0.199	No	N/A	
			Q4	12	11	08/23/2002	09/23/2004	27	0.040	**Yes**	**Increasing**	
	10	485 St. Joseph	Q1	6	4	08/22/2002	03/14/2003	0	0.750	No	N/A	
			Q2	6	1	08/22/2002	03/14/2003	3	0.360	No	N/A	*
			Q3	6	2	08/22/2002	03/14/2003	7	0.136	No	N/A	*
			Q4	6	1	08/22/2002	03/14/2003	3	0.360	No	N/A	*
	23	404 Jefferson	Q4	4	2	10/08/2002	01/13/2003	4	0.167	No	N/A	*
0.80	7	434 Sherman	Q1	12	12	08/23/2002	09/23/2004	4	0.195	No	N/A	
			Q2	12	10	08/23/2002	09/23/2004	27	0.040	**Yes**	**Increasing**	
			Q3	12	9	08/23/2002	09/23/2004	17	0.108	No	N/A	
			Q4	12	8	08/23/2002	09/23/2004	36	0.010	**Yes**	**Increasing**	
1.00	8	157 Joachim	Q1	6	2	08/23/2002	03/17/2003	9	0.068	No	N/A	*
			Q2	6	1	08/23/2002	03/17/2003	1	0.500	No	N/A	*
			Q3	6	4	08/23/2002	03/17/2003	-3	0.360	No	N/A	
			Q4	6	2	08/23/2002	03/17/2003	1	0.500	No	N/A	*

Notes:

* Result is suspect because of the low detection frequency

[1] Properties are ordered as a function of increasing distance from the smelter.

[2] Trend tests were not conducted for properties with fewer than four rounds of sampling.

[3] All censored (nondetect) measurements were set equal to a concentration slightly lower than the minimum detected value.

[4] Monotonic trends are significant for probabilities less than or equal to 0.05; significant negative values for the Mann-Kendall test statistic indicate that trends are decreasing; and significant positive values for the Mann-Kendall test statistic indicate that trends are increasing.

NA No significant trend identified.

TABLE 2

COMPARISON OF RESULTS OF STATISTICAL TESTING FOR MONOTONIC TRENDS (MANN-KENDALL TEST)
IN LEAD CONCENTRATION FOR INDIVIDUAL QUADRANTS AND GROUPED SAMPLES
SAMPLING ROUNDS 7 THROUGH 18
HERCULANEUM LEAD SMELTER SITE - HERCULANEUM, MISSOURI

Distance From Smelter[1] (miles)	House Number	Address	Number of Sampling Events[2]	Sampling Event		Number of Quadrents Tested	Quadrants with Significant Increasing Trend	Grouped Data with a Significant Increasing Trend (Yes/No)	Notes
				First	Last				
0.10	76	329 Station	5	10/30/2003	09/23/2004	2	0	No	
0.20	20	928 Church	11	08/26/2002	09/23/2004	4	4	**Yes**	
0.20	101	339 Curved	4	12/22/2003	09/23/2004	4	1	**Yes**	
0.20	102	959 Main	4	12/22/2003	09/23/2004	4	1	No	
0.25	5	407 Burris	11	08/26/2002	09/23/2004	4	4	**Yes**	
0.25	6	907 Dale	11	08/23/2002	09/23/2004	4	1	**Yes**	
0.25	22	824 Brown	10	08/26/2002	09/23/2004	4	3	**Yes**	
0.25	24	812 Brown	9	11/07/2002	09/23/2004	4	2	**Yes**	
0.40	12	292 Park	12	08/23/2002	09/23/2004	4	3	**Yes**	
0.40	13	562 Reservoir	7	08/23/2002	06/23/2003	3	1	No	
0.40	17	416 Thurwell	11	08/22/2002	09/23/2004	4	3	**Yes**	
0.40	21	295 Broadway	7	08/23/2002	09/23/2004	4	1	No	
0.45	11	525 Joachim	5	08/26/2002	03/17/2003	4	1	No	
0.50	14	440 Thurwell	5	09/16/2002	06/23/2003	4	0	No	
0.50	16	695 Joachim	9	09/16/2002	09/23/2004	4	2	**Yes**	*
0.50	19	407 Hill	11	08/22/2002	09/23/2004	4	2	No	
0.54	9	454 Hill	11	08/22/2002	09/23/2004	4	3	**Yes**	
0.60	4	438 Washington	6	08/22/2002	03/14/2003	4	0	No	*
0.60	18	422 Reservior	12	08/23/2002	09/23/2004	4	1	**Yes**	
0.75	3	441 Main	12	08/23/2002	09/23/2004	4	2	**Yes**	
0.75	10	485 St. Joseph	6	08/22/2002	03/14/2003	4	0	No	*
0.75	23	404 Jefferson	4	10/08/2002	01/13/2003	1	0	No	*
0.80	7	434 Sherman	12	08/23/2002	09/23/2004	4	2	**Yes**	
1.00	8	157 Joachim	6	08/23/2002	03/17/2003	4	0	**Yes**	*

Notes:

* One or more quadrants contains results that may be suspect because of the low detection frequency.

[1] Properties are ordered as a function of increasing distance from the smelter.

[2] Trend tests were not conducted for properties with fewer than four rounds of sampling.